

Level-1B and Level-2 Updates for eMAS Version 1.0 SEAC⁴RS Data

G. Thomas Arnold^{1,2}, S. Platnick¹, J. Myers^{3,4}, Rose Dominguez^{3,4}, K. Meyer^{1,5}, E. Hildum^{3,4}

¹ NASA Goddard Space Flight Center, Greenbelt, Md, ² SSAI, Inc. Lanham, Md, ³ UC Santa Cruz, CA, ⁴ NASA Ames Research Center,

⁵ Earth Science Technology and Research (GESTAR) USRA Columbia, Md,

Introduction

Version 0 “preliminary” Level-1B and Level-2s eMAS SEAC⁴RS data has been reprocessed to version 1.0. Primary modifications to the Version 1.0 Level-1B data include final solar reflectance calibration (bands 1-25) and for the longwave infrared (LWIR) bands (26-38) application of a custom designed filtering algorithm to remove significant multiple-frequency coherent noise artifact. Primary changes to the Level-2 data include modifications to the eMAS cloud mask algorithm, designed to significantly reduce the number of clear sky pixels mis-identified as “cloudy”. Each of these Level-1B and Level-2 modifications are discussed below.

Level-1B Updates

Solar Reflectance Calibration (Bands 1-25)

Final eMAS solar reflectance calibration was derived primarily from an eMAS over-flight of a vicarious calibration site recorded following the SEAC⁴RS deployment on Oct 24th. Applicability of the vicarious calibration data to the SEAC⁴RS data is supported by two factors. The first is the similarity to the eMAS/MODIS (Terra) comparison conducted earlier on the same Oct. 24th flight and presented in Table I. Note the similarities in the adjustment ratios (MAS/MODIS) in columns 2 and 3 as compared to 4. The second factor is the stability of the eMAS calibration for all Houston-based SEAC⁴RS flights, as suggested by both the relative calibration measurements recorded during eMAS pre-flight over a small integrating hemisphere (Figure 1) and also calibration comparison results from three eMAS/Aqua comparisons recorded on 21 August, 06 September and 09 September (the eMAS/MODIS comparisons were discussed in a poster presented at the 2014 SEAC⁴RS Science Meeting).

[Band #]	Central Wavelength (μm) or Cloud Retrieval	Reflectance Based Adjustment Ratio (w/band correction)	Retrieval Adj. Ratio	Vicarious w/MCST Solar Spectral Irradiance
[1]	0.47	1.07		1.06
[2]	0.55	0.95		0.96
[3]	0.65	0.94		0.98
[7]	0.86/tau _{2.1}	0.93	0.92	0.96
[10]	1.6/re _{1.6}	0.97 (0.98)	0.89	0.95
[20]	2.1/re _{2.1}	0.86 (0.93)	0.91	0.94

Table I. Data in Columns 2 and 3 are adjustment ratios (eMAS/MODIS) for collocated - similar view angle eMAS and MODIS (Terra) data for Oct 24, 2013 (adjustment ratios are the scale factors applied to the eMAS post-deployment laboratory calibration data to adjust to MODIS). The 1.6 and 2.1 ratio values in parenthesis include correction for eMAS/MODIS bandpass differences. The Retrieval Adjustment Ratio is the adjustment necessary to produce best agreement of the eMAS cloud optical thickness and effective particle radius data to MODIS.

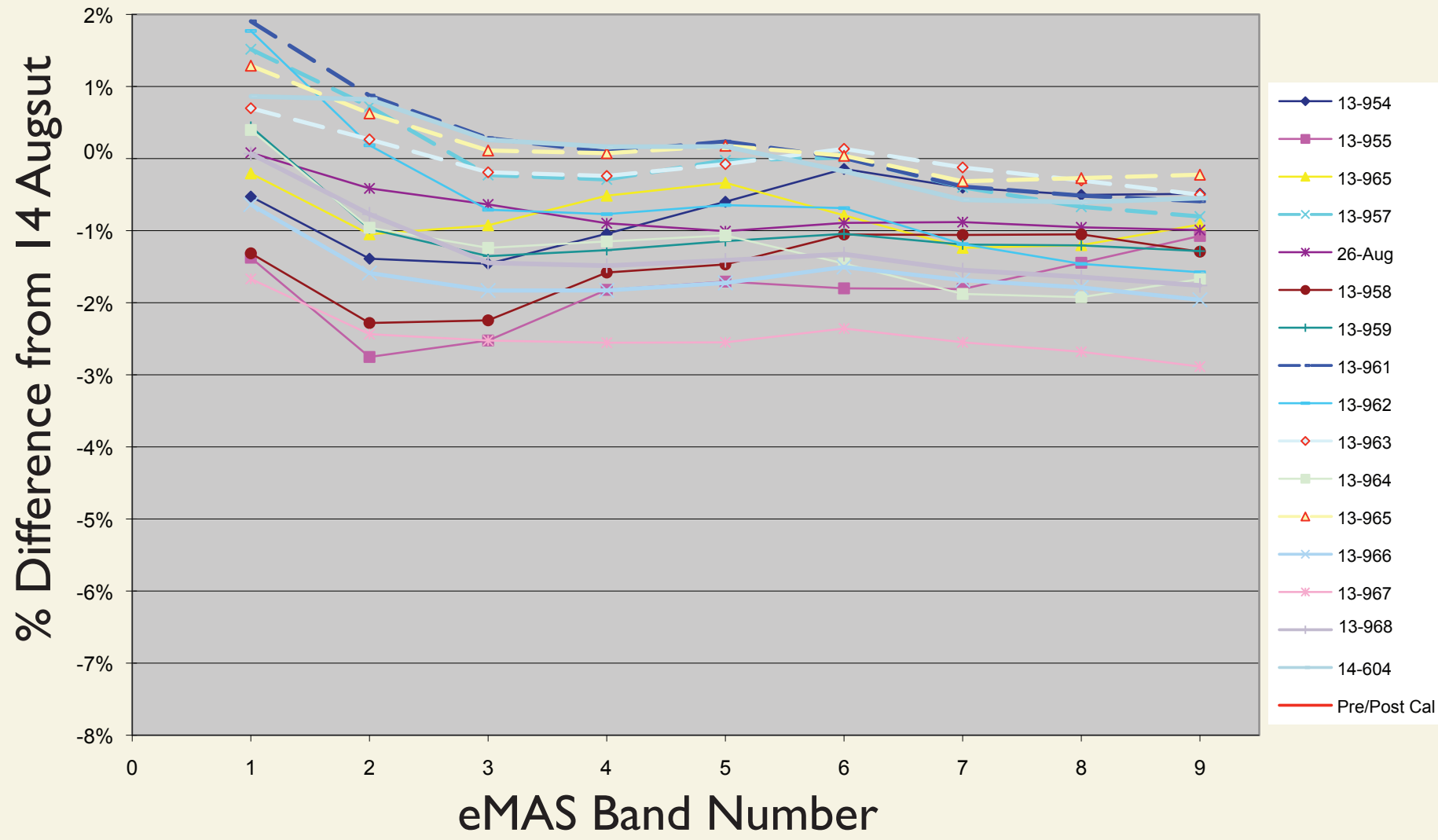


Figure 1. eMAS measurements made over an integrating hemisphere prior to each SEAC⁴RS Houston flight (and the Oct 24 calibration flight) were recorded to allow tracking of the relative eMAS calibration over the course of SEAC⁴RS. The curves above, for eMAS Port 1 (bands 1-9), show little relative calibration change over the course of the SEAC⁴RS. Port 2 bands (10-25) would likely also show little change, but port 2 pre-flight data are unavailable due to optics fogging in the LN₂ dewar in the high Houston humidity.

Prior to the Houston based SEAC⁴RS flights, eMAS flew three flights out of Palmdale (01, 02 and 06 August), but unlike the relatively steady pre-flight hemisphere data for the Houston flights, the pre-flight measurements 02 August and 06 August showed a sizeable change (up to 6-7%). The shift is remarkably similar to the calibration shift noted between the pre and post-SEAC⁴RS deployment laboratory calibrations of eMAS (calibration measurements recorded over a well calibrated 30-inch sphere). The source of the apparent calibration change is unclear, and adds uncertainty to the eMAS 02 August data since it is not clear at what point between the pre-flight measurements the calibration changed.

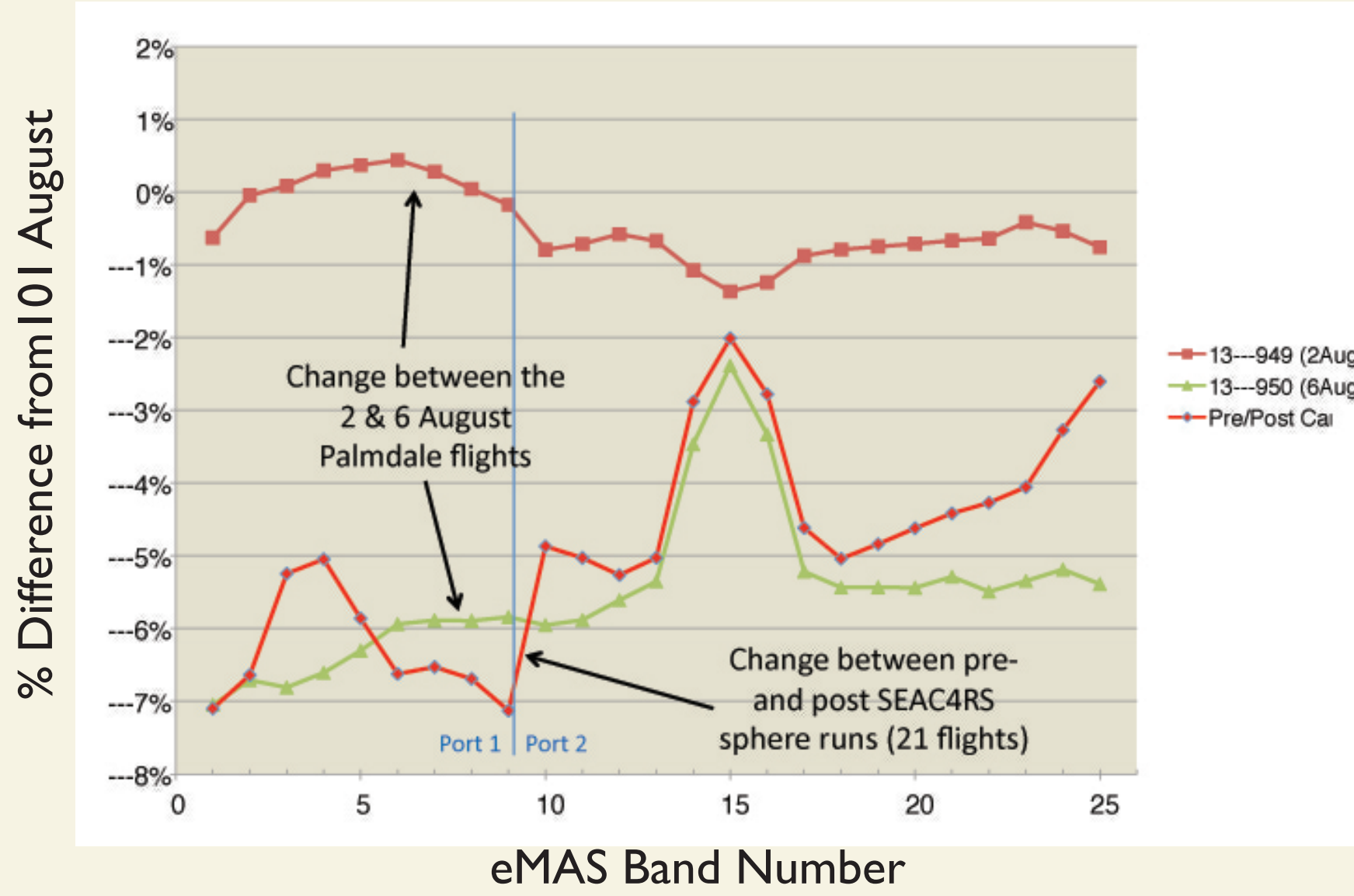


Figure 2. Red curves represent the relative calibration change for the 02 August and 06 August pre-flight calibration measurements to those from the Aug 01 pre-flight. The green curve shows the change in the pre and post-deployment lab calibrations. Note the similarity between the difference in the pre-flight 02 and 06 August calibrations vs the pre and post-deployment laboratory calibration change (Note: bands 14-16 lie in a water vapor absorption region).

eMAS Band Number	Wavelength (μm)	Adjustment Ratio (for data 06 August 2013 and later)	Adjustment Ratio (for data prior to 06 August 2013)
1	0.47	1.061	0.991
2	0.55	0.958	0.898
3	0.65	0.980	0.931
4	0.70	1.010	0.961
5	0.74	1.002	0.947
6	0.82	0.986	0.925
7	0.87	0.958	0.899
8	0.91	1.030	0.965
9	0.95	1.136	1.060
10	1.61	0.947	0.903
11	1.66	0.991	0.944
12	1.72	1.016	0.965
13	1.77	1.102	1.049
14	1.82	0.954	0.954
15	1.88	1.0*	0.979*
16	1.93	1.003	0.976
17	1.98	1.251	1.196
18	2.03	0.974	0.927
19	2.08	0.926	0.883
20	2.12	0.938	0.897
21	2.18	0.906	0.868
22	2.22	0.881	0.845
23	2.27	0.865	0.831
24	2.32	0.862	0.835
25	2.37	0.996	0.971

Table II. Adjustment ratios (based on the eMAS/vicarious calibration comparison) applied to eMAS post-deployment laboratory calibration results. Ratios for data prior to 06 August (column 4) have been adjusted by the ratio of the pre-deployment and post-deployment calibrations (due to the apparent calibration change noted by the pre-flight calibration data between the flights on 02 and 06 August).

Longwave Infrared (LWIR) Band Noise Filtering

Noise Filtering of the eMAS LWIR bands. SEAC⁴RS was the first deployment the new eMAS IR spectrometer, as built by the USU Space Dynamics Laboratory. The data exhibited pronounced coherent noise features, correlated to the operation of a Stirling cryo-cooler, primarily at 60 and 120Hz.. Because the frequency and phase of the noise is not exactly constant, a custom filtering technique (described a poster presented at the 2014 SEAC⁴RS meeting) was developed and applied to the version 1.0 data set. The spectrometer has since been returned to SDL for analysis and modifications to mitigate this effect.

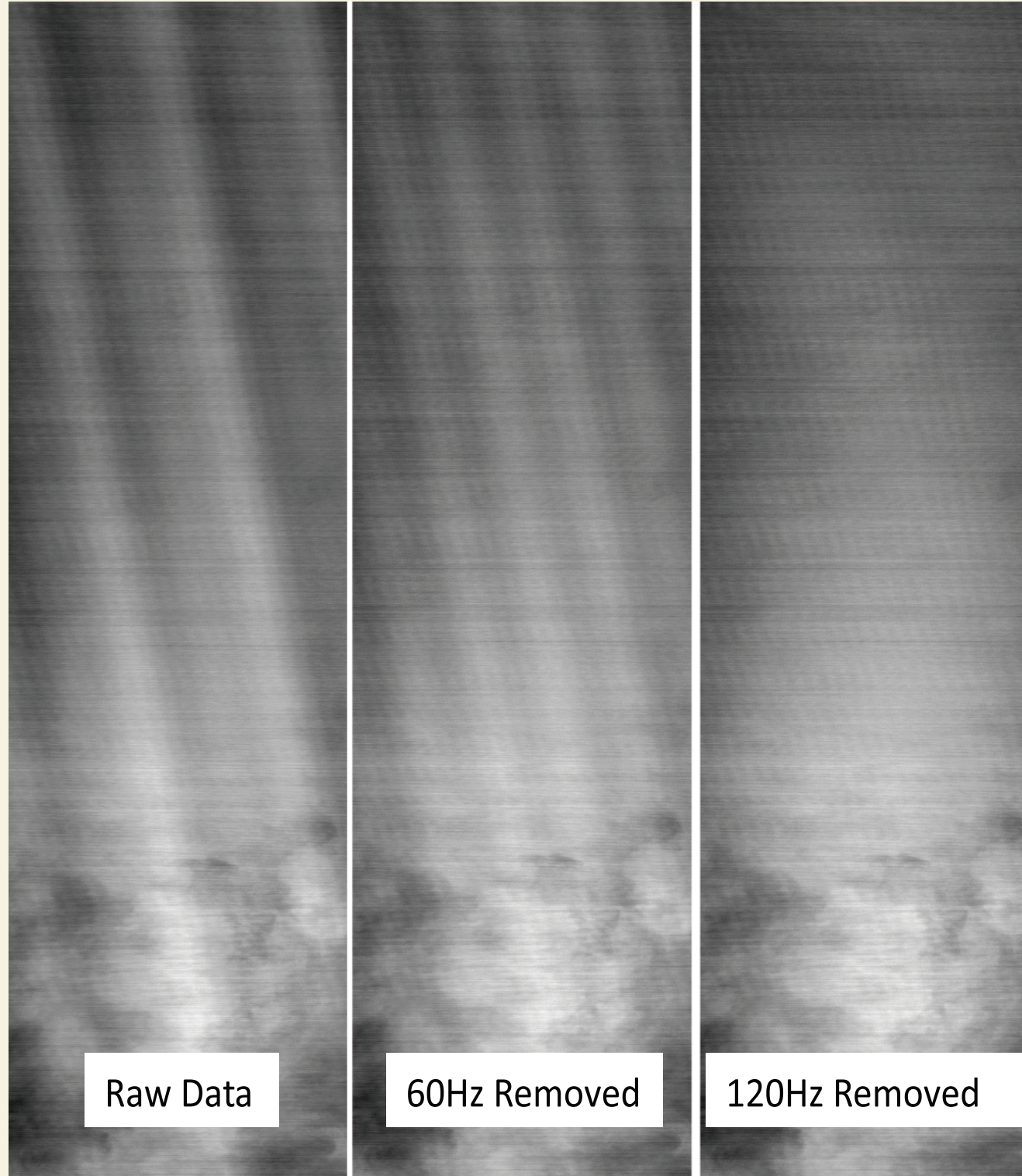


Figure 3. Noise Removal Progression (6.7um band, 9/13/2013, 18:32 Z) 540 Hz high frequency noise is not addressed.

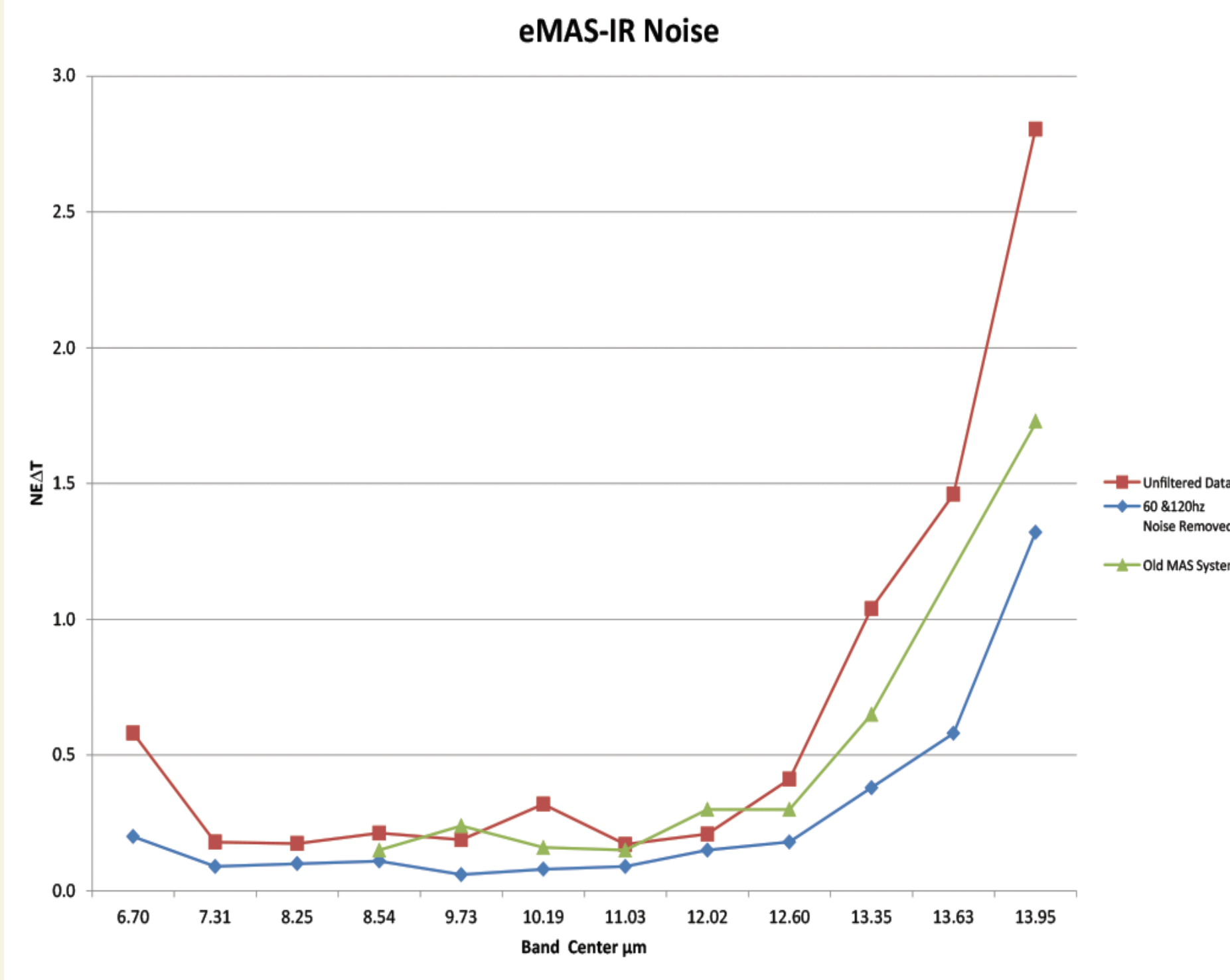


Figure 4. Noise Performance (NEdT) before and after filtering, together with legacy MAS data for comparison.

Level-2 Updates

Cloud Mask Modifications

Since the initial (version 0) data release, changes to eMAS SEAC⁴RS Level-2 data due modifications made to the Level-2 cloud optical properties processing code (in sync with development of MODIS Collection 6 code) has had only minor impact the Level-2 data. More significant effects on Level-2 data though has come from cloud mask modifications. In the preliminary data release, the cloud mask (for data over land) was flagging too much clear sky as cloud. However following considerable investigation, much improved results have been achieved by employing ecosystem dependent threshold modifications to the visible reflectance test and the 11-3.75 μm brightness temperature difference test, and employment of an 11 μm brightness temperature test (for pixels exceeding the cloud mask test thresholds, a pixel is presumed to be clear sky if 11 μm BT > 295K). Considerable testing was done to set the thresholds to reduce the false cloud amount without significantly “clearing” valid cloudy pixels. Figure 5 shows two example tracks before and after application of the cloud mask modifications.

It is worthy to note that while these cloud mask changes do appreciably reduce the false cloud amount, they are considered “SEAC⁴RS specific” and will be reassessed for future eMAS data.

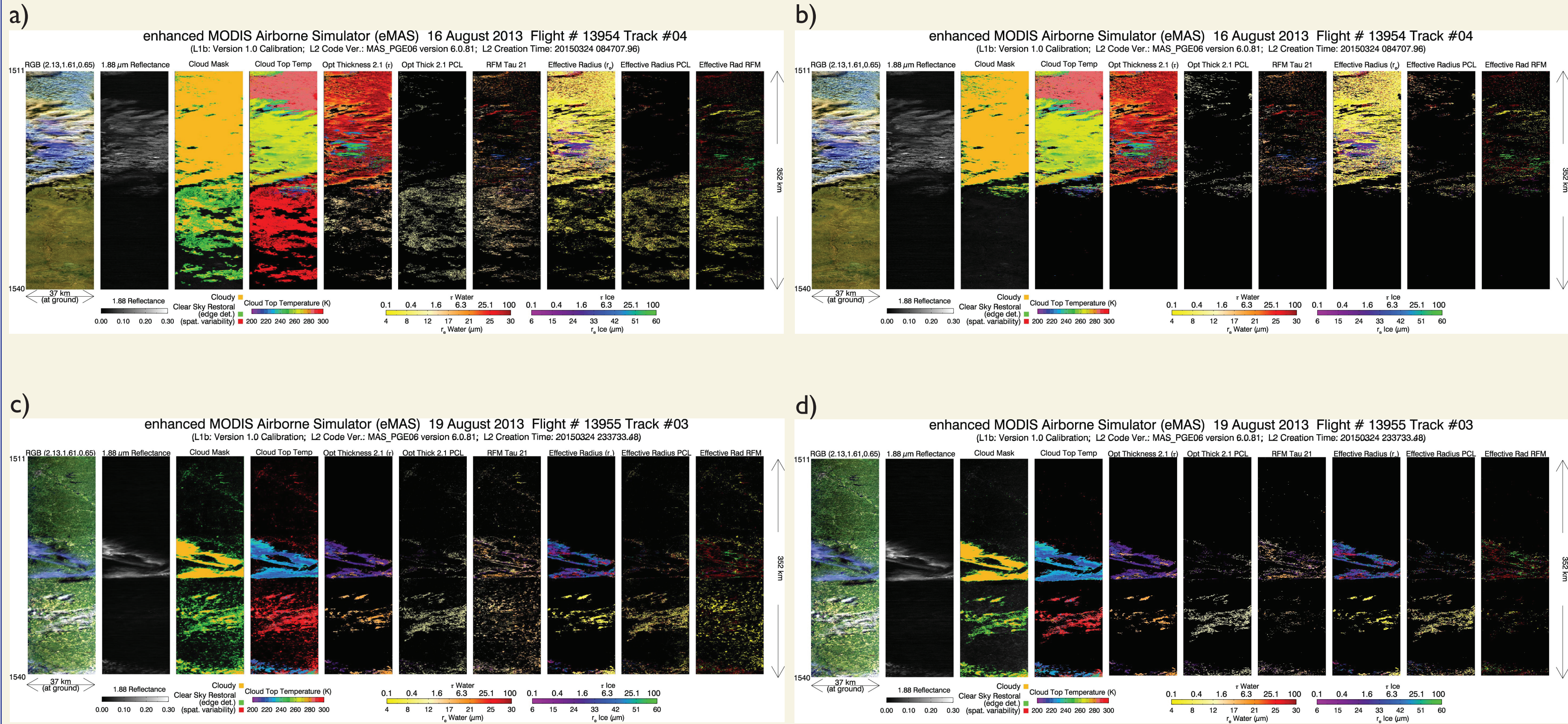


Figure 5 (a-d) Sample eMAS Imagery showing the impact of the cloud mask algorithm changes in reducing the amount of “false” cloud in the cloud mask and cloud optical property retrieval imagery. Imagery on the left is before the changes, images on the right after. In most cases, the false cloud data produced failed retrievals for cloud optical thickness and effective radius, but Figure 5a is a good example where it did not.

Data Availability

Level-1B and Level-2 eMAS data for all Houston and Palmdale SEAC⁴RS flights are available for download from LAADS (*Level-1 Atmosphere and Archive Distribution System*). The eMAS data can be accessed on the LAADS website at: <https://ladsweb.nascom.nasa.gov/data/MAS.html>. MAS and eMAS data within the MAS_eMAS directory is organized by flight number (see the README file there for further details).

In addition documentation is also available in the LAADS archive that describes the eMAS SEAC⁴RS solar reflectance calibration, and also a document that summarizes noteworthy comments about the data for each flight track including the data quality of each track.

Additional information about eMAS and to access Level-1B and Level-2 quicklook imagery can be found on eMAS website at: <http://mas.arc.nasa.gov>. Questions regarding the eMAS data can be sent to tom.arnold@nasa.gov.

Acknowledgements

The authors wish to acknowledge S. Ustin, and M. Whiting, (UC Davis), and C. Brugge, and J. van dan Bosch (JPL) for conducting/analyzing the the vicarious calibration, and J. Zheng, E. Fraim, and H. Su (Ames) for assistance processing the LWIR filtering.